

# “Come to Us, We Have Scooters” – Electric Scooter Sharing and Closed-Campus Micromobility: An Empirical Study on Usage Patterns in Different Pandemic Scenarios



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**Abstract** Shared micromobility concepts, such as electric scooter sharing (ESS), are experiencing explosive growth and adoption in urban centers. An interesting subcategory with only little research attention is the closed-campus micromobility. The scientific literature is lacking in providing evident insights into consumers' behavior in closed-campus micromobility services, especially with respect to the effects of disruptive, threatening events, such as a pandemic. With particular regard to variations of threat severity, this article aims to identify temporal and spatial usage patterns for a closed-campus ESS service of an urban multi-location organization in Stuttgart, Germany. Using the Protection Motivation Theory and the Fundamental Motives Framework for Consumption, the analysis of user data indicates that, in contrast to findings of preliminary studies, the pandemic do heavily affect temporal and spatial usage patterns of closed-campus ESS: The hard lockdown decreases the frequency of ESS use, but only slightly the range of motion. The mobility behavior in the weekly overview varies greatly in the different pandemic scenarios. Roundtrips, however, consistently dominate at every stage, compared to one-way trips. In addition, the study enables to characterize consumer types of closed-campus ESS.

**Keywords** Electric scooter sharing · ESS · Closed-campus · Micromobility · Usage pattern · Disruptive · Threat, pandemic · Protection motivation · German

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## Introduction

Electric micromobility sharing increasingly gain in relevance for policymakers, mobility industry and researchers. They can potentially reduce traffic congestion, greenhouse gas emission and improve individual transport flexibility (Eccarius & Lu, 2020; Liao & Correia, 2020; Rayaprolu & Venigalla, 2020). Especially electric scooter sharing (ESS) are experiencing explosive growth and adoption in urban centers (McKenzie, 2019; Shaheen et al., 2020). The two- or three-wheeled e-scooters have gained attention due to their quick and effective impact in attracting many users in a relatively short time (Almannaa et al., 2021).

In the meanwhile, the Covid-19 pandemic heavily affected the usage and consumer behavior of micromobility sharing. Consumers use products and services more consciously, are increasingly concerned about health risk, social or ecological impact and actively support local businesses (Kim et al., 2021). The pandemic has highly disrupted mobility and consumption patterns, in particular usage patterns with social, ecological and local impact (Kim et al., 2021; Rayaprolu & Venigalla, 2020). In this context, an interesting subcategory of micromobility with only little research attention is electric scooter sharing (ESS) in an intra-organizational context, such as closed-campus solutions, where organizations with large or multiple locations provide e-scooters to their employees/members. These closed-campus micromobility services serve not only as means of transportation to get from one location to another more quickly and flexibly, but also as attractive employee benefit. This article analyzes consumer behavior data of a closed-campus ESS in an urban environment in Germany. It is likely that disruptive, threatening events occur fundamental changes in micromobility behavior, however little is known about the effects of different threat factors in this context, as well as about the extent of behavioral changes in different threat scenarios. Urban micromobility services could be preferred to traditional public transportation on the one hand due to their outdoor use where social distance can be maintained. On the other hand, it could also move towards zero, since sharing objects with strangers is perceived as a risk. This work identifies usage patterns of closed-campus ESS services in different threat scenarios (here: pandemic lockdown scenarios). The analysis can contribute to a deeper understanding about micromobility sharing during disruptive, threatening events.

Currently, only little is known about the impact of disruptive, threatening events on consumers' micromobility behavior. Additionally, the clear lack of evident insights into behavioral patterns in closed-campus micromobility represents a second research gap. This paper sheds light on the effects of disruptive, threatening events, such as a pandemic, on consumers' micromobility behavior. We exemplify our analysis using an internal field laboratory of a closed-campus ESS service in the city of Stuttgart, Germany, and investigate usage patterns before and during different threat scenarios. A previous study by McKenzie (2019) already investigated spatial and temporal usage patterns of ESS in Washington, D.C. With our article, we successively build on this preliminary work by applying it to an urban multi-location

campus in Germany, in addition with a disruptive, threatening event in the form of a global pandemic. Our data analysis addresses the following two research questions:

RQ1: Which temporal and spatial usage patterns of electric scooter sharing (ESS) can be identified in scenarios of varying threat severity?

RQ2: Which consumer types characterize closed-campus ESS?

In order to answer the research questions, this paper is structured as follows: First, we provide an overview of the research literature addressing micromobility and ESS usage patterns. Second, we describe the theoretical embedding, present the methodology and current findings of this study. Finally, we discuss practical and theoretical implications, limitations of the study and provide suggestions for further research opportunities.

## Literature Review and Theoretical Embedding

Recent research literature about micromobility is increasingly devoted to the demand, use and potential impacts of micro-vehicles (Liao & Correia, 2020). The International Transport Forum (ITF) defines micro-vehicles as “vehicles with a mass of no more than 350 kg (771 lb.) and a design speed no higher than 45 km/h” (Santacreu et al., 2020), such as bicycles, e-bikes and pedelecs, e-scooters, kick scooters/bikes or skates (Santacreu et al., 2020; Oeschger et al., 2020). The research literature addresses so far different aspects of micromobility, such as impact (Cottam et al., 2021; Elliot & Susan, 2016; Ma et al., 2019; Shaheen et al., 2013), usage (Caspi et al., 2020; Hardt & Bogenberger 2019; Jing et al. 2021; Reck et al., 2021) or travel behavior (Arnell, 2019; Buehler et al., 2021; Stocker et al., 2016). A selection of studies already investigated usage patterns of e-scooters and e-bike sharing in different contexts (Jing et al., 2021; McKenzie, 2019, 2020; Rodríguez, 2021; Talavera-Garcia et al., 2021).

A few shared micro- or e-mobility studies include the Covid-19 pandemic in their analysis of consumer data. For example, Almannaa et al. (2021) explored the perception of ESS in Saudi Arabia with respect to the pandemic. Approximately half of the 439 respondents believed that Covid-19 would not affect their willingness to ride e-scooters. The study additionally showed that gender, age and the use of ride-hailing services play an important role in respondents’ willingness to use ESS. Li et al. (2020) discussed variations of micromobility behavior before and during the Covid-19 pandemic in Switzerland and found that passengers use micromobility services for longer distance and duration in pandemic times than before. At the meanwhile, the pandemic had only a slight influence on the use of e-scooter services.

Overall, micromobility studies with relation to the pandemic only addressed publicly accessible services so far. Usage patterns of closed-campus micromobility systems, especially with respect to the effects of a pandemic, have not yet been part of the scientific discourse. The preliminary work of McKenzie (2019) forms an

essential foundation to our study findings. His comparison of usage patterns of e-scooter- and bike-sharing in Washington D.C. shows clear differences in the temporal and spatial dimensions. Although the study does not relate to a disruptive, threatening event, the results indicate relevant insights about ESS usage, e.g. that there is a mid-day peak of use and that the mean duration of ESS trips is roughly 5 min.

In summary, we identified the literature gap that studies about micromobility usage patterns mainly refer to public ESS services so far. The literature is lacking in insights on the use of closed-campus micromobility. In addition, previous research does not consider in their theoretical embedding the impact of disruptive, threatening events, such as a pandemic, on micromobility behavior and on how consumers respond to protect themselves from the threatening situation. A deeper understanding is needed at the intersection of threat scenarios and upcoming behavioral changes towards health-oriented and sustainable mobility (Marquart & Schuppan, 2022). Therefore, we derived a set of relevant research variables from recognized consumer behavior theory referring to outstanding threatening events.

*Protection Motivation Theory* (Maddux & Rogers, 1983; Rogers, 1975): The Protection Motivation Theory (PMT) is a model of disease prevention/health promotion and investigates the effect of fear appeals on persuasion. It has generated research for several decades (Floyd et al., 2000) and delivers constructs affecting consumer decision-making in times of emergency or disease. Selected constructs can be applied very well to consumers' micromobility behavior in outstanding situations with an increased need for protection, such as a pandemic (Cismaru & Lavack, 2006; Kim et al., 2021). Especially the constructs *vulnerability*, *severity*, *efficacy*, and *costs* are empirically proved to have an impact on persuasion measures (Cismaru & Lavack, 2006) and need to be taken into consideration for evaluating the effects of a pandemic on the consumers' micromobility behavior. It is critical to holistically study the PMT constructs regarding the emotional response and changing behavioral patterns that have emerged during the pandemic (Kim et al., 2021). Our findings are supposed to be the first to use PMT constructs for micromobility research and to provide relevant guidance for introducing PMT constructs in mobility behavior.

*Fundamental Motives Framework for Consumption* (Griskevicius & Kenrick, 2013): The framework of fundamental motives for consumption (FMFC) considers consumer motivations from an evolutionary perspective. It identifies a set of functionally discrete motivational states linked to self-protection and mating and presents seven variables with impact on the choice of consumption (Kenrick et al. 2010): (1) *evading physical harm*, (2) *avoiding disease*, (3) *making friends*, (4) *attaining status*, (5) *acquiring a mate*, (6) *keeping a mate*, and (7) *caring for family*. In terms of our database and research questions, the constructs for self-protection (*evading physical harm* and *avoiding disease*) can serve as framework constructs.

## Methodology

The database to this study comes from an internal field laboratory “DHBW Drive” of the Baden-Wuerttemberg Cooperative State University (DHBW). It has been implemented in cooperation with two industry partners (MIMO drive, EAR Innohub) and represents the first e-scooter sharing system in a German closed-campus university environment. Approximately 7000 students and 400 employees can freely move between five campus locations (mobility hubs) located ca. 1500 m (5000 ft) one of each other. The users can ride and park the scooters temporal/spatial freely as well as free of charge. However, the trips must start and end in one of the DHBW mobility hubs on the university campuses. To use one of the 70 e-scooters, users must register with a university email address in an app available for Android and iOS. At the mobility hubs, the e-scooters are charged using an in-house developed docking system. Over the first data collection period, October 2020 to February 2021, more than 1200 students and university staff registered, over 2000 bookings were made, and ca. 9000 km (5600 miles) were covered.

We have split our analysis in four investigation periods according to the different pandemic stages in Germany, defined by the trade union “Erziehung und Wissenschaft” Baden-Württemberg (GEW) (Baden-Württemberg, 2021). Table 1 describes the different pandemic stages, investigation periods and project dates.

Among others, the data collection included logs for users (age, gender, user ID), trips (start/end times, location, trip length, trip duration) and vehicles location (scooter reports with latitude and longitude coordinates, actual active trips). During the DHBW Drive registration process, we asked the users for authorization to use their personal and mobility data in an anonymized form for research purposes. The sample includes 1231 valid users (Sept 2021). DHBW Drive project staff members did not enter the sample. In the study project period (Oct 13, 2020 – Jan 31, 2021), 70 two-wheeled e-scooters by Segway were used, 2454 trips were made and a sum of 861,576 vehicle data points (latitude, longitude, time markers, reservation status) were collected. The anonymized data were locally analyzed using MATLAB (R2020b) routines developed for this study.

**Table 1** Investigation periods/pandemic stages and project dates

Investigation periods	
Oct 13, 2020	<b>Before lockdown</b> (until Nov 1, 2020): Project start, no restrictions from government.
Nov 2, 2020	<b>Soft lockdown</b> (until Dec 15, 2020): Social contacts limited to ten people in Stuttgart, gastronomy, sports and culture closed, schools and daycare centers open, second online semester at universities.
Dec 16, 2020	<b>Hard lockdown 1</b> (until Jan 4, 2021): Only shops for daily needs open, Christmas in a small circle, no sale of fireworks, evening/night curfew (also on New Year’s eve).
Jan 5, 2021	<b>Hard lockdown 2</b> (until Jan 31, 2022): Extension of restrictions, additionally schools and day-care centers closed.

## Results

The users are 1231 registered persons, 28% female and 72% male, with a mean age of 22.6 years (SD = 6.05 years). They consists of 1169 students and 62 university employees. In the subsample of inactive users (who got inscribed, but never used the system), we count slightly more females (31%) than in the subsample of active users (24% female).

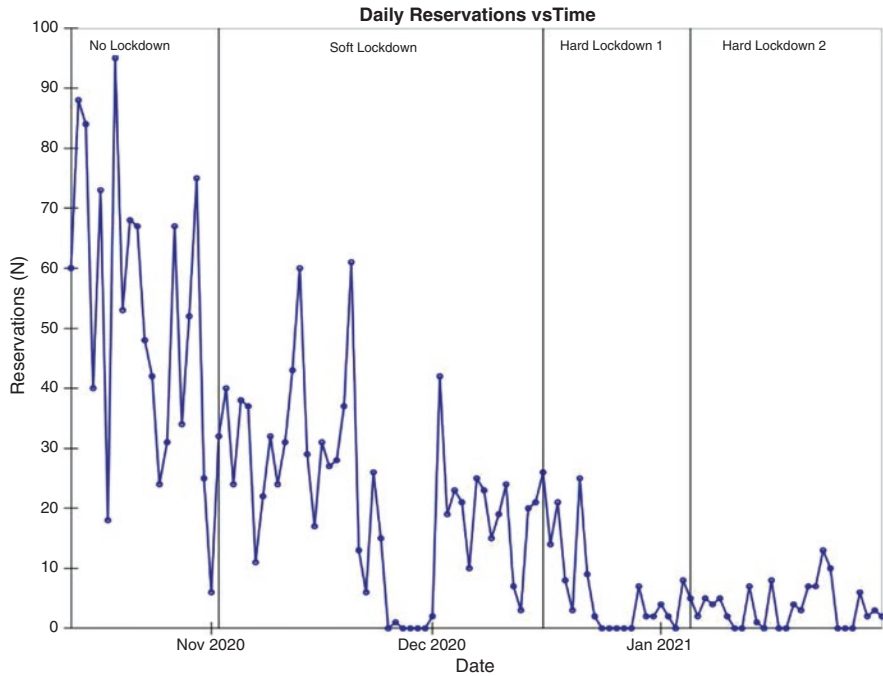
On average, trips are 25 min and 4.3 km (2.7 miles) long. Thereby the duration ranges from 1 min up to 3 h; the distance ranges from less than 1 km up to 27 km (<0.6–16.8 miles). The most frequently traveled distance was between 0 and 1 km (0–0.6 miles) (23%), the second between 1 and 2 km (0.6–1.2 miles) (19%). This supports previous findings that e-scooters are particularly strong for the “first/last mile” (Liao & Correia, 2020; Smith & Schwietermann, 2018), including closed-campus e-scooters. In this context, e-scooters offer more benefits for the “first/last mile” than public transport or walking (Liao & Correia, 2020), since these closed-campus scooters are free of charge (*costs*) for university members and generally faster than walking (*efficacy*).

Comparing usage in the different pandemic stages, it is noticeable that before lockdown the most used times of the week were Thursday afternoon, Wednesday mid-day/afternoon, Monday mid-day/afternoon and Saturday night (simultaneous scooters usage of 12 and more). In total, Thursday was the day with the highest number of bookings over the week.

During the soft lockdown, the most used times of the week were Monday/Tuesday/Thursday mid-day and Sunday afternoon (simultaneous scooters usage of 9 and more). However, in total, the day with the most bookings on average during soft lockdown was Friday.

In hard lockdown 1, Monday afternoon, Wednesday afternoon and Friday afternoon became the times of the week when most scooters were used simultaneously (6 and more). In summary, Monday was the most popular day for the scooter usage during this period. The usage decreased sharply in hard lockdown 2. The most frequent times were Saturday afternoon and Friday mid-day (5 and more). Saturday appears as the most popular day for ESS usage during hard lockdown 2.

Looking at the number of daily bookings in the pandemic, it is apparent that during the project start phase in October 2020, we recorded the highest scooter usage. End of November 2020 shows a short collapse of bookings, which interestingly bounce slightly back in the beginning of December 2020. This may be explained by the fact that Covid-19 incidence levels and, consequently, the perceived *severity* of the disease increased rapidly during this period. Before lockdown, we count 938 trips per week and 197 weekly trips during soft lockdown. The hard lockdown 1 records 111 trips per week, while the hard lockdown 2 only comes to 44. Figure 1 shows how the usage decreases continuously during soft lockdown, hard lockdown 1 and 2. The assumption is reasonable that this is due to the fact that users felt a higher *vulnerability* and tried to *avoid disease* and to *evade physical harm* by moving through the city center only when justified.

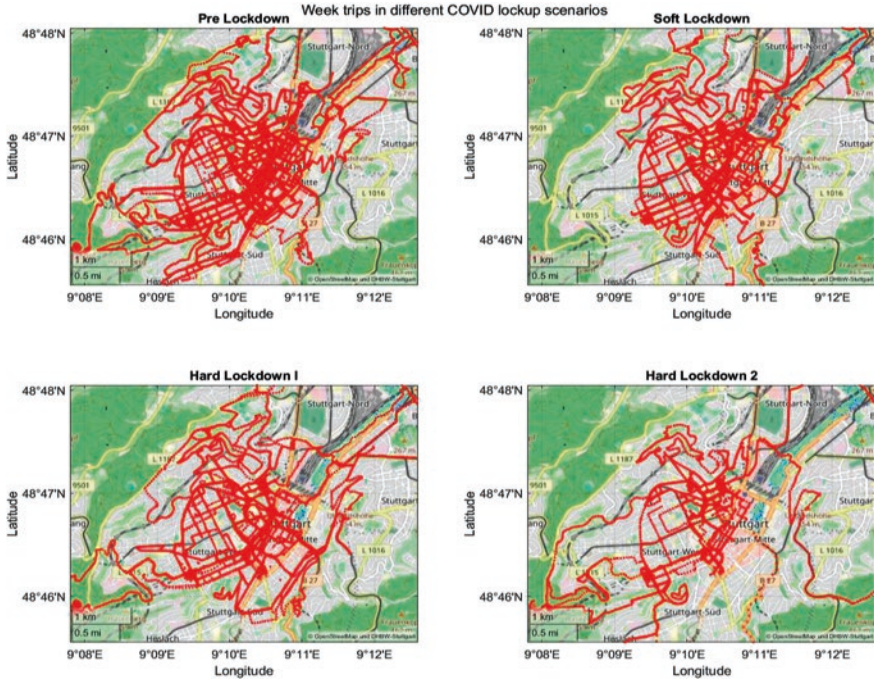


**Fig. 1** Covid-19 lockdown effect on usage

It is noteworthy at this point, that in all four stages of the pandemic, roundtrips heavily predominate, compared to one-way trips. Most ESS users book a scooter at one campus location and then return it to the same location. It appears that consumers use the scooters mainly for personal and work-related errands, rather than for moving between two campus locations/mobility hubs. To provide background information regarding travel destination or usage intention, further data need to be collected like parking location and user surveys.

With regard to usage during the course of the day in different pandemic phases, it is noticeable that before lockdown and during soft lockdown, a peak of the day in usage is always around lunchtime (12–1 pm). In contrast, during hard lockdown 1 and 2, the daytime peak of usage shifts to the afternoon (2–4 pm). This is likely due to the fact that most users were no longer spending full workdays at the university during this period, and therefore it was more cost-saving (*costs*), secure (*avoiding disease*) and efficient (*efficacy*) to take lunch breaks at home.

Concerning spatial usage, Fig. 2 shows movement patterns and the coverage in the city center of Stuttgart in all four pandemic scenarios. Before lockdown, when usage was at its highest, the most traveled routes are concentrated in the inner-city center (e.g. pedestrian zone, shopping mile, castle), where the five campuses are located, with large coverage throughout the downtown area. The spatial mobility behavior changes in the soft lockdown, when the most popular routes still focus on the inner-city center; however, the perimeter suddenly becomes noticeably smaller.



**Fig. 2** Spatial coverage in different Covid-19 pandemic lockdown scenarios

The range of motion expands again in the hard lockdowns, while usage decrease remarkably, especially in hard lockdown 2.

The Baden-Wuerttemberg Cooperative State University Stuttgart currently has 8370 potential user (DHBW Stuttgart, 2021). Almost 15% (1231 users) have already registered for the ESS service. Consulting the phases of the Diffusion of Innovations by Rogers (1975), the adoption is in the transition from the *early adopters* to the *early majority*. We assume that the hard lockdown disrupted and delayed the predicted diffusion curve. For future research, it would be interesting to monitor the phase development (early majority, late majority, laggards) without lockdown interference. We expect that the ESS adoption would restart at the “before-lockdown” point of the diffusion curve and continue according to Rogers (1975). At this point of the monitoring, we can support this expectation, since new customers’ growth is currently exponential.

In order to answer RQ2, Table 2 presents the six identified consumer types of the closed-campus ESS service, according to the user data. The consumer types are not mutually exclusive and can overlap to some extent. This means that an individual user can also be assigned to two types. Comparing the behavior of the types in the different pandemic scenarios, the worktime consumer always predominates. Regardless of the pandemic stage, by far the majority of consumers use e-scooters during worktime (Monday-Friday, 8 am–12 pm and 2 pm–5 pm). The food-catcher



**Table 2** Closed-campus ESS service consumer types

Consumer types	
(1) The “once and never again” consumer	Users who used the service only once → 18% of the sample
(2) The “registered and never used” consumer	Users who registered, but never used the service → 48% of the sample
(3) The frequent consumer	At least three times usage during project period → 23% of the sample
(4) The worktime consumer	Usage Monday-Friday, from 8 am–12 pm to 2 pm–5 pm → 56% of the sample
(5) The free-time consumer	Usage on weekdays after 5 pm → 42% of the sample
(6) The food-catcher	Usage 12 pm–2 pm, round trip → 22% of the sample

is present before and during soft lockdown but recedes during hard lockdown 1 and 2. The free-time consumer describes the second largest user group before lockdown, which reduces significantly during hard lockdown 1 and expands again slightly during hard lockdown 2.

## Conclusion and Discussion

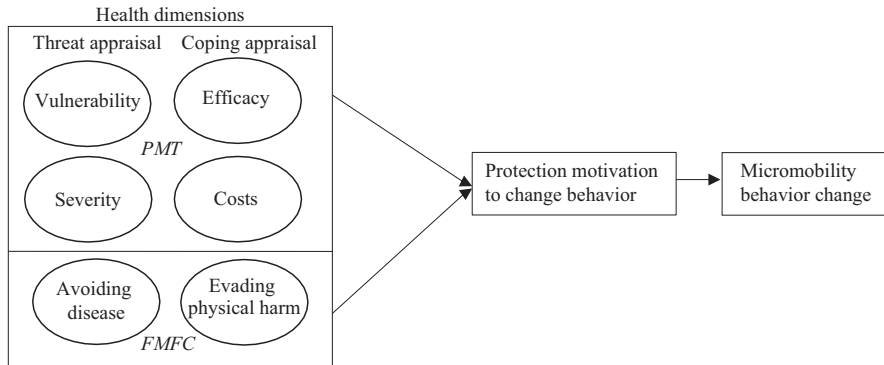
Since disruptive, threatening events, such as a pandemic, can occur fundamental changes in micromobility behavior, this article identifies usage patterns of a German closed-campus ESS service in different threat scenarios. First, this article presents two identified research gaps: (1) incomplete knowledge about the impact of disruptive, threatening events on consumers’ micromobility behavior, (2) lack of evident insights into consumer behavior in closed-campus micromobility services. In the following, this paper introduces preliminary studies and theoretical approaches relevant to this study. After showing the methodology of data collection and analysis, this article represents the key findings of the data analysis. In summary, the findings show that disruptive, threatening events, such as a pandemic, do heavily affect temporal and spatial usage behavior in ESS. In contrast to the findings of preliminary studies (Almanaa et al., 2021; Li et al., 2020), our results cannot confirm that the pandemic would only have a slight influence or no influence on the use of ESS, in our case a closed-campus ESS service in Germany. Based on the gender and age distribution of our sample (mean age = 22.6 years, 72% male), it is very reasonable to assume that similar to the findings by Almanaa et al. (2021), gender and age also affect the willingness to use closed-campus ESS services. According to the findings by McKenzie (2019), we cannot completely confirm that there is a daily mid-day peak of use and that the mean duration of ESS trips is roughly 5 min. In our closed-campus ESS service, the mean trip duration is 25 min. The mid-day peak of use is visible before hard lockdown; however, it shifts to the afternoon during hard lockdown 1 and 2.

Overall, the Covid-19 pandemic highly decreases the frequency of the ESS use, but only slightly the range of motion. The usage behavior in the weekly overview varies greatly in the different pandemic scenarios. Roundtrips, however, consistently dominate at every stage (compared to one-way trips).

This study provides relevant insights to both usage patterns of closed-campus micromobility services as well as their variations caused by disruptive, threatening events. “Due to business secrecy issues, it is often difficult to obtain data from private shared mobility providers” (Liao and Correia 2020), which results in data scarcity and less comparability with other ESS- or micromobility solutions. We aim to counteract the problem by building an own internal field laboratory “DHBW Drive” in a closed-campus environment. The data enables to characterize first consumer types of closed-campus ESS services. Furthermore, the results can uncover similarities and differences between micromobility services.

Regarding the theoretical contribution, this study extends our understanding of behavioral changes in micromobility patterns during disruptive, threatening events. Previous mobility research lacks of attempts to develop specific theory to explain behavioral responses to threat (Clubb & Hinkle, 2015). Since Covid-19 was leading to drastic changes in consumer behavior and micromobility data during a global, disruptive event is scarce, a theoretical framework that provides a deeper understanding about the determinants of behavioral changes in micromobility patterns is highly needed (Kim et al., 2021; Marquart & Schuppan, 2022). Against this background, our user data provide empirical evidence of supporting PMT in mobility research and introduce constructs which are likely to determine micromobility behavior. The PMT constructs *vulnerability*, *severity*, *efficacy*, and *costs* pertain to not only the evaluation of individuals but also the society (Kim et al., 2021; Maddux & Rogers, 1983; Rogers, 1975). Our findings underline the relevance of incorporating these threat appraisal and coping appraisal constructs in a framework for overarching micromobility behavior change (Marquart & Schuppan, 2022). Regarding the Fundamental Motives Framework for Consumption (FMFC), the health constructs *evading physical harm* and *avoiding disease* are included in the framework as well. According to the data, a suitable conceptual framework includes (but not limited to) the following constructs, which we suggest to use for follow-up studies (Fig. 3):

Concerning managerial implications, the study provides deeper, quantitative insights on ESS usage patterns, which are valuable to consider, on the one hand, in closed-campus/urban transportation planning and policy with respect to shared micromobility services and alternative closed-campus/urban transportation solutions. To operators of ESS as well as employers with closed-campus micromobility solutions, on the other hand, our findings offer a quantitative basis for planning decisions. For example, our data on the maximum number of scooters used at the same time in different scenarios is relevant information for scooter providers and ESS project planners. Furthermore, this study implies precisely that practitioners must consider threat factors to predict protection motivation to change micromobility behavior in disruptive, threatening events.



**Fig. 3** Conceptual framework

Nevertheless, the study faces some limitations, which provide starting points for future research.

Due to the decline in usage during hard lockdown 1 and 2, the database was reduced, which meant that even small changes in usage figures could lead to outliers and biases. This should be kept in mind when interpreting the numbers. Furthermore, the survey do not provide consumer behavior insights about determinants of usage intention and the pandemic impact. This needs to be investigated through user surveys or interviews to verify or deny the assumed reasons for changing movement patterns. Additionally, at this point of the study, we are not able to track data about parking activities (e.g. GPS location, parking time). For interpreting the data, it would be interesting to analyze what the consumer is likely to do in the parking time. We are actually working to eliminate this limitation, which offers remarkable research potential. Moreover, we plan to analyze more variables of individuals or smaller user groups in the future, for example, if demographic variables correlate with the micromobility behavior in pandemic and non-pandemic times. Furthermore, it could be interesting to investigate if the variables related to mating (e.g. *making friends, attaining status, acquiring a mate, keeping a mate*) increase the motivation to use ESS, both in pandemic and non-pandemic times.

For future research, the identified usage patterns of our study can be tested for ESS in other countries or closed-campus micromobility services in other economic sectors. It is important to investigate to which extend the identified consumer types are applicable to publicly accessible ESS or micromobility services. Lastly it would be interesting how the “willingness to share” electric scooters is developing in the era of post pandemic.

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